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Research Paper

DESIGN AND FABRICATION A METAMATRIAL BASED ABSORBER FOR GSM AND DCS BAND APPLICATION

Mehdi Bahadorzadeh Ghandehari[1]* and Mohammad Jahanbakht[2]

*Corresponding Author: Mehdi Bahadorzadeh Ghandehari, ✉ m.bahadorzadeh@mshdiau.ac.ir

A novel Metamaterial Absorber (MA) based on rectangular shaped resonators with slot has been proposed in this paper. This metamaterial unit cell absorber possesses a nearly wide angle perfect absorption of incidence wave andpolarization independence. The absorption is occurred in GSM and DCS frequencies bands. The absorptivity is as high as 99% at around 0.9 (GHz) and 1.8 (GHz) frequencies. An important feature of this method is using a slot in the outer loop to simply tuning the resonant frequencies of this absorber. The proposed absorber represents a good absorption for different angle of incident.

Keywords: Metamaterial absorber, GSM & DCS band, Wide incident angle absorption

INTRODUCTION

Recently Electromagnetic metamaterials (MTMs) have been widely used in various applications. These kinds of absorbers are defined as artificial and effectively homogeneous electromagnetic structures with unusual and unique properties that do not exist in the nature. Metamaterials were first introduced theoretically by Veselago (1968) his research was followd by Pendry *et al.* (1998 and 1999) and Smith *et al.* (2000).

These construct engineered electromagnetic materials are composed of natural materials such as highly conductive and shaped metals and dielectric materials that will be selected according to the frequency range and the application.

Using a gap in the structure of the absorber has been used to tune the resonant frequency of metamaterialabsorber. The basic goal is to design an absorberwithmaximum the absorption coefficient. It is equivalent to minimize both the transmission (T) and reflection (R) coefficients in the equation A = 1-T-R, where A is absorption coefficient.

In this paper, we propose a novel planar tunable metamaterial absorber which absorb the electromagnetic wave at nearly 0.9 (GHz)

[1] Assistant Professor, Department of Electrical Engineering, College of Engineering, Mashhad Branch, Islamic Azad University, Mashhad, Iran.

[2] Department of Electronic Engineering, Shahr-e-Qods Branch, Islamic Azad University, Tehran, Iran.

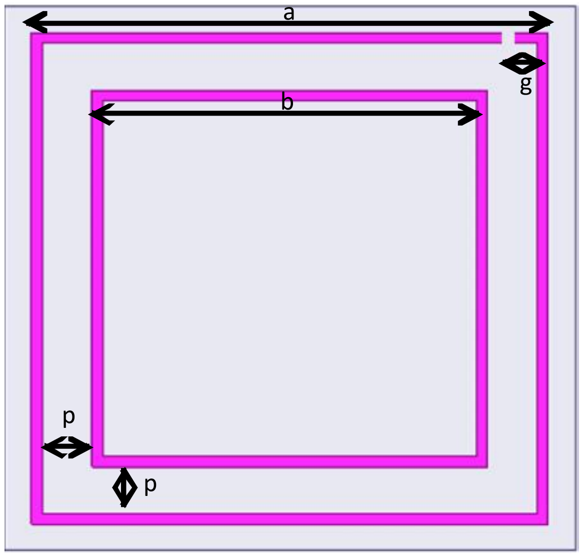
and 1.8 (GHz) with absorption rate about 99%. It is observed that the metamterial absorber is polarization insensitive for both Transverse Electric (TE) and Transvers Magnetic (TM) waves. By comparing measured and simulated results, it could be seen that the absorption for different polarization are the same. The proposed metamaterial absorbers in many articles have only one absorption frequency (Fallahzadeh *et al.*, 2012; Huang *et al.*, 2013; and Seman and Khalid, 2014), also some of them do not have the feature of simple construction and the absorption is not close to the maximum value (Singah *et al.*, 2013) but the proposed metamaterial absorber in this paper has the advantage of simply fabrication and the maximum absorption at two absorbing frequencies. Also multiband and incident angle independent absorbers have been proposed in (Mehdi Bahdorzadeh Ghandehari *et al.*, 2015; and Bahdorzadeh Ghandehari *et al.*, 2015).

DESIGN AND SIMULATION

As shown in Figure 1, the proposed metamaterial unit cell is considered as a rectangular shape. The metallic structures on the top and bottom layers of the substrate are chosen as copper, the electrical conductivity and thickness is $5.8 \times 10^7 (s/m)$ and 0.036 (mm), respectively. The substrate of absorber is FR4 ($\varepsilon_r = 4.3, \tan\delta = 0.025$) with 1.6 (mm) thickness.

The simulation is done by Ansoft HFSS with periodic boundary conditions. The boundary surfaces perpendicular to the incident electrical field (E) are defined as Perfect Electric Conductor (PEC) surfaces, while the surfaces perpendicular to the incident magnetic field (H) are defined as Perfect Magnetic Conductor (PMC) surfaces. Finally, the surfaces perpendicular to propagation vector (k) are defined as open ports.

Figure 1: Unit Cell Geometry and Design Parameters



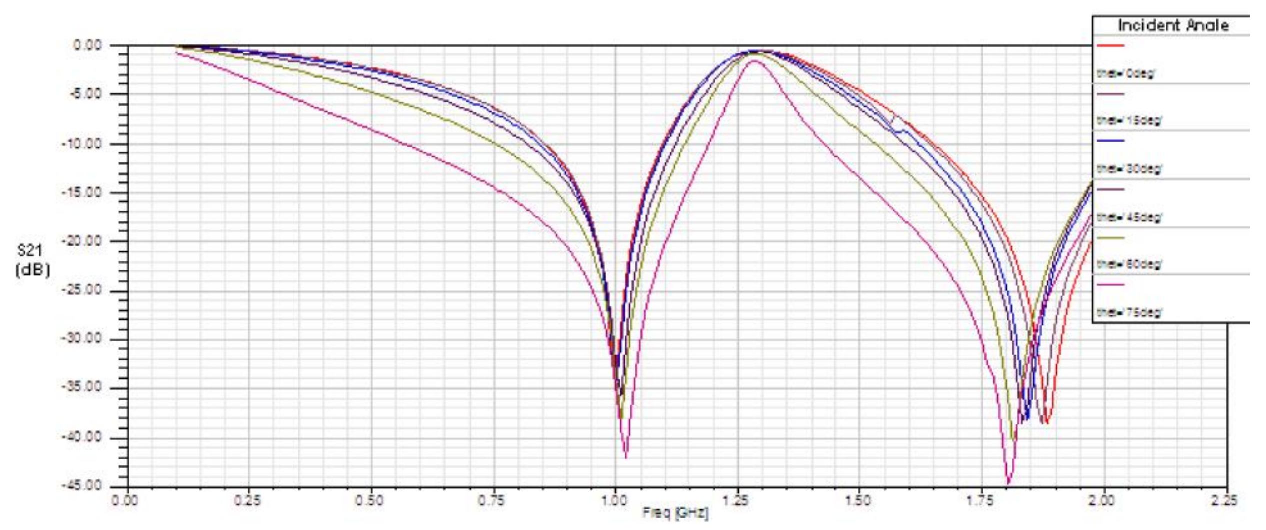
Note: a = 46 mm, b = 34 mm, p = 4 mm, g = 1.2 mm.

The absorption is calculated as $A(\omega) = 1 - |S_{11}|^2 - |S_{12}|^2$, where R(ω) = $|S_{11}|^2$ represents the reflection and T(ω) = $|S_{12}|^2$ represents the transmission. The absorption of the proposed structure is shown in Figure 2. It is evident that near the frequencies of 1 (GHz) and 1.8 (GHz) the absorption reaches its maximum value and the absorption rate reaches to 94% and 99%, respectively.

The first absorption frequency is occurred due to the largest perimeter rectangular and the smallest rectangular will result in the second absorption.

Impedance matching is has a crucial role in minimizing the reflection. In circuit model point of view we could assume the structure as an Electric-LC resonator. At resonant frequency a conduction currents will be induced on the absorber. Also there is a

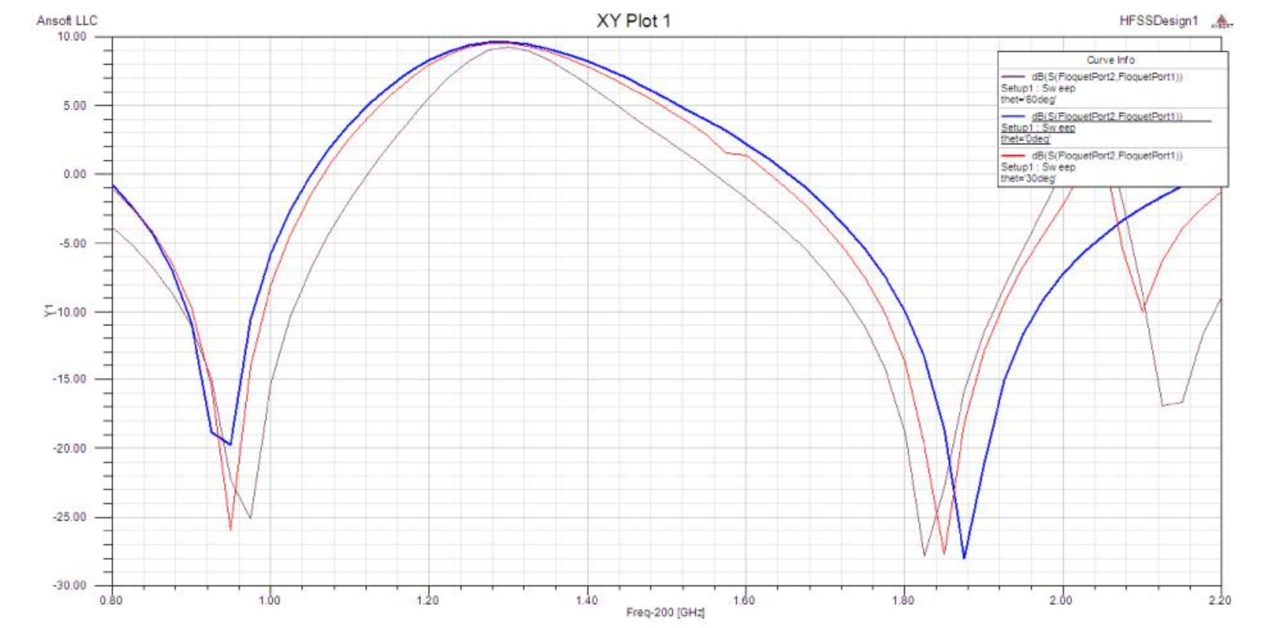
Figure 2: Simulated Reflection and Absorption of the Proposed Metamaterial Absorber



magnetic response associated with a circulating displacement current between the resonator and the ground plane (bottom side of substrate). The electric and magnetic response appeared simultaneously at the absorption frequency. In this resonance condition, the effective impedance is dened as $Z(\omega) = \sqrt{\frac{\mu(\omega)}{\varepsilon(\omega)}}$.

In order to make the minimum reflection, the effective impedance has to be matched to free space impedance. This phenomenon is happened in the resonance frequency.

Figure 3: Simulated Absorption of the Proposed Metamaterial Absorber at the Different Incident of Polarization Angles Ranging from to for TE Incident Radiation



Moreover, due to the resonant loss in the metallic resonator and the dielectric loss of substrate, the transmission in the metamaterial absorber is effectively reduced.

Also by using tuning gap another resonant frequency will be added. The role of this gap is also adjusting the first and second resonant frequencies of the absorber. The optimum size for the best matching has been found and representedin Figure 3. In comparison to Figure 2 the first resonant frequency has been adjusted to GSM band.

In order to find the influence of polarization and incident angle on the performance of the proposed metmaterial absorber, the absorption under different angle of incident wave is demonstrated in Figure 3. As shown in this figure, the strength of absorption is very good for threedifferent incident angles.

Simulation results show that the metamaterial absorber can be operated for a wide range of arbitrary polarizations and provides a very well absorption for all polarization angles.

As the next step, the effect of the impinging wave angle on the frequency response of the absorber for both TE- and TM-polarized electromagnetic waves is analyzed. The simulated absorption characteristics as a function of the frequency for the TE- and TM-polarized waves for different angles are obtained. The results of simulations Show that this absorption is completely independent from polarization of incident wave.

It is seen that the main peak of the absorption is around unity again (99%) for TE and TM cases at different angles. The frequency shift can be explained by the changing of the polarization angle from 0^o to 60^o. The results have been presented on Table 1.

Table 1: Absorption for Different Incident Angles at DCS Band

Incident Angle	Absorption Rate
0	-28.1
30	-27.5
60	-27.3

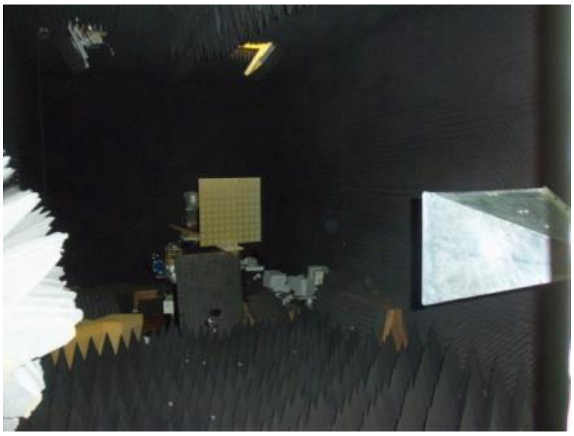
So, the proposed metamaterial unit cell is exible in tuning the resonant frequencies and has multi directional structure, and very small and negligible differences are observed between the cases of TE and TM when the polarization angle is changed. The simulated results show that the proposed metamaterial absorber can be operated for a wide range of incident angles with arbitrary polarizations.

FABRICATIONAND EXPERIMENT RESULTS

To verify the full-wave simulations, a 10 × 10 unit cells sample (500 mm × 500 mm × 1:5 mm) was fabricated by printing a planar array of designed hexagonal shaped structure on the front side. A complete ground plate was placed on the back side of a FR-4 substrate. The thickness of the substrate is considered 1.5 mm and Printed-Circuit-Board (PCB) technology was used for fabrication is used. The photograph of the experimental sample of proposed MA is shown in Figure 4. A vector network analyzer Agilent E8363C and two linear polarized horn antennas were used to transmit TEM waves in the range from 0.8 GHz to 2.2 GHz to the sample and receive the reflected signals. Because the location of the sample was far enough from the horn antennas, the incidence can be recognized as normal to the sample which is depicted in Figure 5. As demonstrated in Seman and Khalid (2014), the experimental measurement

Figure 4: Photograph of Fabrication of Proposed Metamaterial Absorber

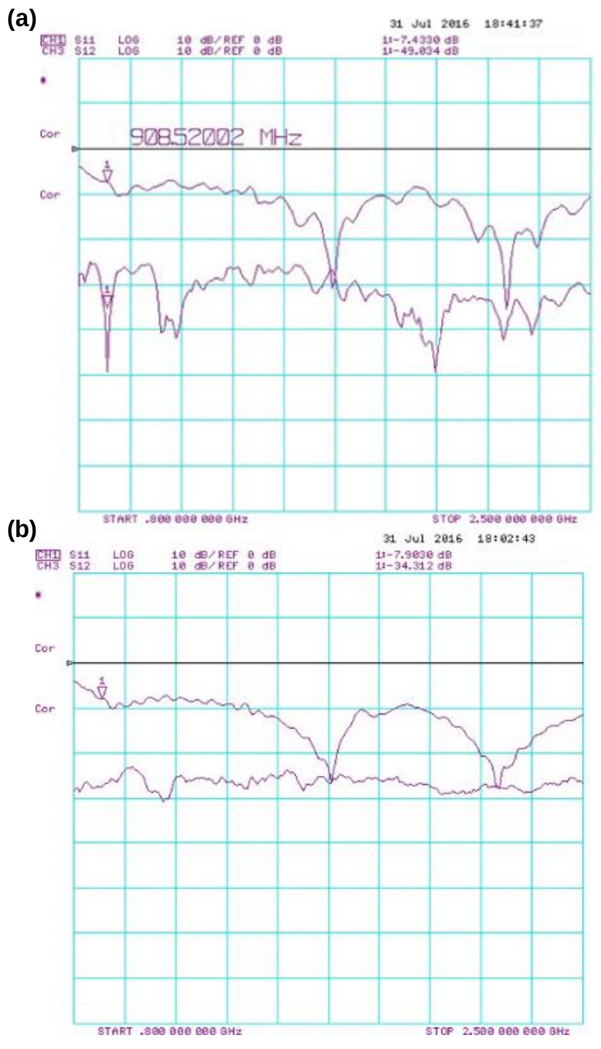
Figure 5: Photograph of Measurement Setup for Proposed Metamaterial Absorber



is carried out in two steps. In the first step, the reflection and transmission measured through S_{11} and S_{21} scattering parameters.At the next step the absorber was placed between to antenna at the far field region respect to antennas.

The result of measured reflection coefficient (S_{11}) and absorption (S_{21}) of the proposed metematerial absorber have been shown in Figures 6a and 6b which are with absorber

Figure 6: The Reflection Coefficient (S_{11}) and Absorption (S_{21}) of the Experimental Proposed Metematerial Absorber (a) With Absorber (b) Without Absorber



and without absorber respectively. As it can be seen there is no different between present and absent of absorber for S_{11} case while in the case of the S_{21} a good absorption is clear.

A comparison between measured and simulated of the proposed metamatrial absorber has been presented in Figure 7. As it is evident a good agreement between simulation and measurement has been reached. In the second step, the fabricated sample of the metamaterial absorber is tested and the S parameters are recorded. The differences between the measured results of the first and second steps represent the modified reflection coefficient from the proposed MA.

Figure 7: The Measured and Simulated Absorption of TE Mode as a Function of the Frequency

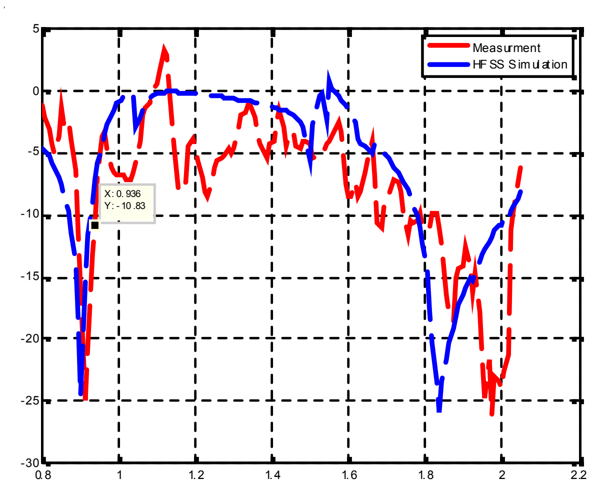
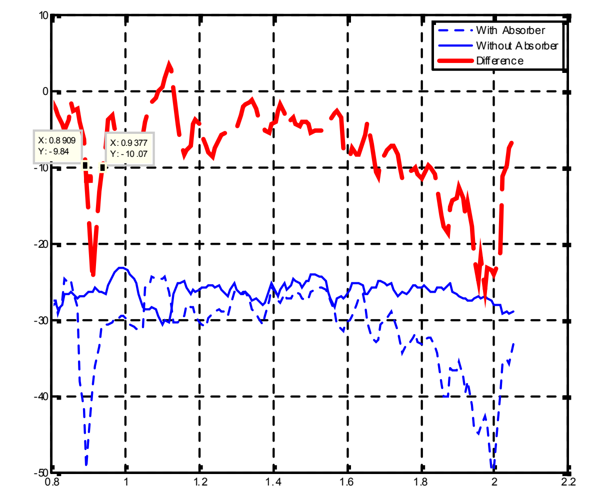


Figure 8: The Measured and Simulated Absorption of TE Mode as a Function of the Frequency



The reflection coefficient and the absorption of the experimental proposed metematerial absorber are shown in Figure 7. At Figure 8 the performance of the absorber to attenuate the desired bands has been represented.

The measured and simulated absorption of TE and TM modes as a function of the frequency have been shown in Table 2. It is observed that a very good attenuation at desired bands has been reached.

Table 2: Bandwidth and Attenuation at DCS and GSM Bands

Resonant Frequency	F_{min}	F_{max}	BW	Attenuation at F_r
908 MHz	890	938	48 MHz	24 (dB)
1980 MHz	1805	2015	210 MHz	25 (dB)

CONCLUSION

In this paper, a novel metamaterial unit cell absorber based on rectangular shape has been presented. Simulations demonstrated that due to the gap in the main loop, the absorption frequencycould be tuned. Metamaterial absorbers that were used in many articles have only somefixed absorption frequencies, but in this paper maximum absorption is observed in twodifferent frequencies which are tuned through the gap. Compared to other articles, absorption is very close to its maximum value. So, it was found that the absorber is polarization independent and could be worked for a wide angle of incidence. The geometric parameters because of the presence of the gap that inuence the resonance of the absorber could be further discussed in future works. It is evident that the absorbing frequency could be shifted by adjusting the space between rectangular and the size of the gap. Also, the fabrication results of the proposed metamaterial absorber demonstrated that the simulation and experimental results are in a good agreement.

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